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Short Communication

Repellency of garlic extract to European starlings

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Garlic and garlic oil were recently exempted from pesticide registration requirements, increasing the attractiveness of these substances as candidate vertebrate repellents. Because anecdotal evidence suggests that garlic may repel birds, the present experiment was designed to evaluate the aversiveness of garlic to European starlings (*Sturnus vulgaris*). Samples of feed were mixed with garlic oil to produce concentrations ranging from 1.0–0.1% (vol./mass). All garlic concentrations reduced consumption relative to consumption of untreated feed in two-cup choice tests ($P < 0.05$). These results are consistent with the possibility that garlic oil may be used to repel these birds. Published by Elsevier Science Ltd

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Garlic extract has been employed as a blackbird repellent in North Dakota (G. Linz, unpublished observations). This use may stem from the recent development of deer repellents that contain garlic (e.g. Plant Protec Garlic, Plant Protec, Oak Run, CA), as well as published evidence that herbivores (and some omnivores) avoid sulfurous odors (Mason, Epple, and Nolte, 1994). While anecdotal reports and some data suggest that snow geese, *Chen carulescens* (Mason and Clark, 1996) and Canada geese, *Branta canadensis*, (Mason *et al.*, 1994) avoid sulfurous odors and sulfur-containing vegetation (e.g. wild mustard, *Brassica nigra*), there is no evidence that omnivorous passerines (e.g. *Agelaius* spp., and European starlings, *Sturnus vulgaris*) respond likewise. Recently, the US Environmental Protection Agency published a notice in the Federal Register exempting 40 specific chemicals and natural products including garlic and garlic oil from pesticide registration requirements. Because exemption significantly reduces the costs of commercialization, there is an increased likelihood that garlic products may be marketed as bird repellents. Accordingly we designed the present experiment to investigate the aversiveness of garlic oil to European starlings. Starlings were selected because they exhibit high olfactory sensitivity (Clark and Mason, 1987) and are a pest in a variety of agricultural contexts (Johnson and Glahn, 1994).

Materials and methods

We randomly selected 20 starlings from the laboratory colony. Birds were individually caged (61 × 36 × 41 cm) under a 12:12 light:dark cycle, and permitted free access to Purina Flight Bird Conditioner (hereafter referred to as feed; Purina Mills, St Louis, Mo.), crushed oyster shell grit and tapwater.

We obtained garlic oil from Roure Fragrances (Teaneck, NJ), and mixed it with samples of feed to produce the following oil concentrations: 1.0, 0.5, 0.1, 0.05 and 0.01% (volume/mass, v/m). This concentration range matched the effective range of known repellents such as methyl anthranilate (Mason, Adams and Clark, 1989), and included the concentration of oil (0.2% v/m) commonly found in garlic cloves (Lawson, 1993).

During a 5-day pretreatment period, we gave all birds two cups of feed (20 g/cup) at 08:00 h (EST) daily. At 10:00 h, we removed the food cups from the cages, and weighed the feed remaining in each cup. Between 10:00 and 18:00, birds were permitted free access to feed and tapwater. Overnight, we deprived the birds of feed to assure measurable consumption during the subsequent test.

At the end of the pretreatment period, we randomly assigned the birds to five groups (n = n/group). During a 5-day treatment period, we presented each group with a different counterbalanced order of garlic oil concentrations. During each test session, one cup contained feed adulterated with garlic while the other contained untreated feed. As in pretreatment, tests occurred between 08:00–10:00 h, plain feed was available *ad libitum* between 10:00–18:00 h, and birds were food-deprived overnight.

We used a two-factor repeated measures analysis of variance to evaluate the data. The factors in this analysis were concentration and cup. Mean pretreatment consumption from cups was included in the analysis as '0%' extract. Tukey tests (Winer, 1962) were used to isolate differences ($P < 0.05$) among means.

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Table 1. Mean consumption of garlic extract treated and plain feed by European starlings in 2-h two-cup choice tests. Means with different superscripts are significantly different ($P < 0.05$)

Garlic extract concentration (% vol./mass)	Mean consumption of treated feed ± standard errors of the means	Mean consumption of untreated feed ± standard errors of the means
1.0	1.8 ± 0.1^a	3.9 ± 0.4^b
0.5	1.8 ± 0.2^a	3.7 ± 0.3^b
0.1	2.0 ± 0.15^a	3.8 ± 0.25^b
0.05	2.2 ± 0.1^a	3.9 ± 0.2^b
0.01	2.2 ± 0.15^a	3.6 ± 0.15^b
0.0	2.8 ± 0.2^a	2.5 ± 0.15^a

Results

There were differences among concentrations ($F = 2.4$; 5,95 d.f.; $P < 0.04$) and between cups ($F = 10.24$; 1,19 d.f.; $P < 0.01$). The interaction between these factors was also significant ($F = 3.77$; 5,95 d.f.; $P < 0.01$), and the analysis was interpreted in terms of this highest order effect. Post-hoc tests showed that all garlic treatments reduced consumption relative to untreated food. While there appeared to be slight decreases in repellency with decreasing garlic oil concentration, the differences were not significant (*Table 1*).

Discussion and management implications

Garlic oil is aversive to starlings in two-cup feeding tests. Moreover, avoidance of treated feed is comparable to that elicited by other avian repellents presented within the same concentration range (e.g. Mason, Adams and Clark, 1989). Whether garlic oil would be avoided by passerines in the absence of alternatives or by species that are more granivorous than starlings remain topics for further investigation. Generally, omnivorous birds like starlings are more sensitive to chemical cues than granivorous passerines (Mason *et al.*, 1991), and a variety of factors including food deprivation, palatability, and availability of alternative foods can affect avoidance (Reidinger and Mason, 1983). We suggest additional experiments to investigate this possibility, as well as to assess the concentration range required to elicit avoidance when untreated feed is unavailable.

Our results are also consistent with a growing body of evidence that, regardless of species, genus or taxa, herbivores (and some omnivores) avoid sulfurous odors. Two plausible explanations can be offered for these repellent effects. One is that herbivores avoid sulfurous odors because predator odors typically contain sulfur (Albone, 1984; Mason *et al.*, 1994). The second is that vegetation containing selenium often has a sulfurous, garlic-like odor (H. Mayland, personal communication). The odor could serve as a sensory cue for the toxicant.

While cautious about extrapolating from the laboratory to the field, our data are consistent with the possibility that garlic oil may have utility as a bird repellent in some situations. At present, garlic oil is applied to sunflowers as a bird feeding deterrent (G. Linz, unpublished observation), and it may be useful with other grain crops. Because use of this substance requires no formal registration, commercialization would be inexpensive. We suggest further testing with birds in aviaries and field settings.

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